

WHAT IS CLAIMED IS:

1. An electron beam physical vapor deposition coating apparatus comprising:

a coating chamber containing a coating material, the coating chamber being operable at an elevated temperature and a subatmospheric pressure;

5 an electron beam gun projecting an electron beam into the coating chamber and onto the coating material, the electron beam gun being operable to melt the coating material and to evaporate molten coating material;

10 means for supporting an article in the coating chamber so that vapors of the coating material deposit on the article;

15 a condensate hood within the coating chamber and at least partially surrounding the support means, the condensate hood having a first reflective member located within the coating chamber such that an article supported on the support means is between the first reflective member and the molten coating material, the first reflective member being movable between first and second positions relative to the molten coating material, the first position being closer to the support means than the second position such that an article supported by the support means is subject to more reflective heating from 20 the molten coating material when the first reflective member is in the first position than when in the second position; and

25 means for moving the first reflective member relative to the condensate hood.

30 2. An electron beam physical vapor deposition coating apparatus according to claim 1, further comprising a shroud surrounding the first reflective member when in the second position, the shroud inhibiting gas flow between the condensate hood and the first

reflective member.

3. An electron beam physical vapor deposition coating apparatus according to claim 1, further comprising means for controlling the first reflective member, the controlling means causing the first reflective member to move away from the molten coating material as the temperature within the coating chamber rises.

4. An electron beam physical vapor deposition coating apparatus according to claim 1, further comprising a second reflective member adjacent the molten coating material such that an article supported by the support means is subject to reflective heating from the second reflective member.

5. An electron beam physical vapor deposition coating apparatus according to claim 4, further comprising means for moving the second reflective member toward and away from the molten coating material so as to increase and decrease, respectively, the reflective heating from the second reflective member to the article.

6. An electron beam physical vapor deposition coating apparatus according to claim 5, wherein the second reflective member is a ceramic material or is coated with a ceramic material.

7. An electron beam physical vapor deposition coating apparatus according to claim 5, further comprising a plurality of the second reflective member adjacent the molten coating material, the moving means being operable to move each of the plurality of second reflective members toward and away from the molten coating material.

8. An electron beam physical vapor deposition

coating apparatus according to claim 1, wherein the molten coating material is contained by a crucible.

9. An electron beam physical vapor deposition coating apparatus according to claim 8, wherein the electron beam is projected onto the coating material to define an electron beam pattern on the coating material, the apparatus further comprising means for projecting a separate electron beam pattern on the crucible for evaporating droplets of the molten coating material on the crucible, the separate electron beam pattern having a higher intensity than the electron beam pattern on the coating material.

10. An electron beam physical vapor deposition coating apparatus according to claim 8, wherein the crucible comprises a first member that surrounds and retains the molten coating material and a second member secured to the first member and surrounding an unmolten portion of the coating material.

11. An electron beam physical vapor deposition coating apparatus according to claim 10, wherein the first and second members of the crucible define an annular-shaped cooling passage therebetween.

12. An electron beam physical vapor deposition coating apparatus according to claim 11, wherein the first member of the crucible has a wall subjected to heating by the electron beam, the wall defining a portion of the cooling passage and having a minimum thickness of not more than 10 mm.

13. An electron beam physical vapor deposition coating apparatus according to claim 1, further comprising an outlet adjacent the molten coating material within the coating chamber, the outlet introducing a gas

5 into the coating chamber, and means for controlling the flow rate of the gas from the outlet into the coating chamber, the control means being located outside the coating chamber but immediately adjacent the outlet within the coating chamber.

10 14. An electron beam physical vapor deposition coating apparatus according to claim 1, further comprising a viewport for viewing the article and the molten coating material within the coating chamber, the viewport being fluid-cooled and having a magnetic particle seal.

15 15. An electron beam physical vapor deposition coating apparatus according to claim 14, wherein the viewport provides a stereoscopic view of the coating chamber.

16. An electron beam physical vapor deposition coating apparatus according to claim 1, wherein a higher pressure is maintained within the condensate hood than in a remainder of the coating chamber.

20 17. An electron beam physical vapor deposition coating apparatus according to claim 1, wherein the condensate hood has an opening through which the electron beam passes, the opening having a cross-sectional area approximately equal to that of a pattern defined by the electron beam at the intersection with the condensate hood.

25 18. An electron beam physical vapor deposition coating apparatus according to claim 1, further comprising:

30 a preheat chamber adjacent the coating chamber for preheating an article supported by the support means prior to introducing the article into the coating

chamber;

a loading chamber adjacent the preheat chamber and opposite the coating chamber;

5 means within the loading chamber for causing motion of the article while supported by the support means;

a first door to the loading chamber for loading and unloading the article from the support means; and

10 a second door to the loading chamber for accessing the motion-causing means.

19. An electron beam physical vapor deposition coating apparatus according to claim 18, further comprising a first passage between the loading chamber and the preheat chamber and a second passage between the preheat chamber and the coating chamber, each of the first and second passages having a minimum dimension of at least 250 mm.

20. An electron beam physical vapor deposition coating apparatus according to claim 1, wherein the condensate hood is fluid cooled.

21. An electron beam physical vapor deposition coating apparatus according to claim 1, further comprising at least one screen detachably secured to the condensate hood.

25 22. An electron beam physical vapor deposition coating apparatus according to claim 21, further comprising spring pins securing the screen to the condensate hood.

30 23. An electron beam physical vapor deposition coating apparatus according to claim 1, further comprising a diffusion pump for evacuating the coating chamber and a throttle valve for regulating the

evacuation of the coating chamber by the diffusion pump and maintaining the subatmospheric pressure within the coating chamber.

24. An electron beam physical vapor deposition
5 coating apparatus according to claim 1, further comprising:

10 a preheat chamber adjacent the coating chamber for preheating an article supported by the support means prior to introducing the article into the coating chamber; and

15 a diffusion pump for evacuating the preheat chamber and a throttle valve for regulating the evacuation of the preheat chamber by the diffusion pump and maintaining a subatmospheric pressure within the preheat chamber.

25. An electron beam physical vapor deposition coating apparatus according to claim 1, further comprising means for detecting a system vacuum leak.

20 26. An electron beam physical vapor deposition coating apparatus according to claim 1, wherein a first portion of the coating chamber is movable between an operating position in which the first portion is mated with a second portion of the coating chamber, and a maintenance position in which the first portion is
25 separated from the second portion.

27. An electron beam physical vapor deposition coating apparatus according to claim 26, further comprising a movable platform beneath the coating chamber when the coating chamber is in the maintenance position.

30 28. An electron beam physical vapor deposition coating apparatus according to claim 1, further comprising at least two ion sensors for sensing the

subatmospheric pressure within the coating chamber, the ion sensors being independently operable to enable selective operation of one of the ion sensors without interrupting coating of the article.

5 29. An electron beam physical vapor deposition coating apparatus according to claim 1, further comprising at least one rotatable magazine supporting a plurality of ingots of the coating material beneath the coating chamber, the magazine aligning at least one of the ingots with an aperture to the coating chamber for feeding the ingots into the coating chamber.

10 15 30. An electron beam physical vapor deposition coating apparatus according to claim 29, wherein the magazine is laterally movable beneath the coating chamber for laterally positioning the coating material within the coating chamber.

20 31. An electron beam physical vapor deposition coating apparatus according to claim 1, further comprising:

at least one chamber within the electron beam gun through which the electron beam passes;

means for evacuating the chamber such that the chamber is at a lower pressure than the coating chamber; and

25 32. An electron beam physical vapor deposition coating apparatus comprising:
an orifice through which the electron beam passes within the electron beam gun, the orifice separating the chamber from the coating chamber, the orifice having a diameter and a length of less than 30 mm and 120 mm, respectively.

30 33. An electron beam physical vapor deposition coating apparatus comprising:

a coating chamber operable at an elevated temperature and a subatmospheric pressure;

a crucible within the coating chamber;
an ingot of a ceramic material located in the
crucible;

5 an electron beam gun mounted to the coating
chamber for projecting an electron beam into the coating
chamber and onto the ingot, the electron beam gun being
operable to melt the ceramic material, form a pool of
molten ceramic material within the crucible, and
evaporate the molten ceramic material;

10 a rake for supporting and manipulating an
article in the coating chamber so that vapors of the
ceramic material deposit on the article;

15 a condensate hood within the coating chamber
and at least partially surrounding the rake, the
condensate hood having a reflective member located within
the coating chamber such that an article supported with
the rake is between the reflective member and the molten
ceramic material, the reflective member being movable
between first and second positions relative to the molten
20 ceramic material, the first position being closer to the
rake than the second position such that an article
supported with the rake is subject to more reflective
heating from the molten ceramic material when the
reflective member is in the first position than when in
25 the second position;

means for controlling movement of the
reflective member between the first and second positions
thereof, the controlling means causing the reflective
member to move away from the molten ceramic material as
30 the temperature within the coating chamber rises;

reflective material adjacent the ingot of the
ceramic material such that an article supported with the
rake is subject to reflective heating from the reflective
material; and

35 a manipulator arm projecting into the coating
chamber for moving the reflective material toward and

away from the molten ceramic material so as to increase and decrease, respectively, the reflective heating from the reflective material to the article.

33. An electron beam physical vapor deposition
5 coating apparatus comprising:

a coating chamber operating at an elevated temperature and a subatmospheric pressure;

at least two ingots of a ceramic material projecting into the coating chamber;

10 at least two electron beam guns mounted to the coating chamber for projecting electron beams into the coating chamber and onto the ingots, the electron beam guns operating to melt the ceramic material, form molten pools of the ceramic material, and evaporate the molten
15 pools, each of the electron beam guns comprising first and second chambers within the electron beam gun through which the electron beam passes, means for evacuating the first and second chambers such that the first and second chambers are at a lower pressure than the coating chamber, and an orifice separating the second chamber from the coating chamber, the orifice having a diameter and a length of less than 30 mm and 120 mm, respectively;

20 means for supporting an article in the coating chamber so that vapors of the ceramic material deposit on the article;

25 a preheat chamber adjacent the coating chamber for preheating the article when supported by the support means within the preheat chamber prior to introducing the article into the coating chamber;

30 a loading chamber adjacent the preheat chamber and opposite the coating chamber;

35 means within the loading chamber for causing motion of the article while supported by the support means;

a condensate hood within the coating chamber

and at least partially surrounding the support means, the condensate hood having a reflective member located within the coating chamber such that the article is between the reflective member and the molten pools of the ceramic material, the reflective member being movable between first and second positions relative to the molten pools, the first position being closer to the support means than the second position such that the article is subject to more reflective heating from the molten pools when the reflective member is in the first position than when in the second position;

means for controlling movement of the reflective member between the first and second positions thereof, the controlling means causing the reflective member to move away from the molten pools as the temperature within the coating chamber rises;

reflective material adjacent the ingots of the ceramic material such that the article is subject to reflective heating from the reflective material;

a manipulator arm projecting into the coating chamber for moving the reflective material toward and away from the molten pools so as to increase and decrease, respectively, the reflective heating from the reflective material to the article;

at least two crucibles supporting the ingots within the coating chamber, each of the crucibles comprising a first member that surrounds and retains a corresponding one of the molten pools of the ceramic material, each of the crucibles comprising a second member secured to the first member and surrounding an unmolten portion of the ceramic material, the first and second members defining an annular-shaped cooling passage therebetween;

at least two rotatable magazines supporting a plurality of ingots of the ceramic material beneath the coating chamber, each of the magazines aligning at least

one ingot with an aperture to the coating chamber for feeding the ingot into the coating chamber, each of the magazines being movable along a linear path beneath the coating chamber for laterally positioning the ingots within the coating chamber; and

5 a viewport for viewing the article and the molten pools of the ceramic material within the coating chamber, the viewport being fluid-cooled and having a magnetic particle seal, the viewport providing a stereoscopic view of the coating chamber.

10 34. A method of operating an electron beam physical vapor deposition coating apparatus, the method comprising the steps of:

15 mounting an article on a support within a loading chamber that is adjacent a preheat chamber;

establishing an absolute pressure of between 10^{-3} mbar and 10^{-1} mbar within the loading chamber and the preheat chamber;

20 moving the article into the preheat chamber;

establishing an elevated temperature and an absolute pressure of between about 10^{-3} mbar and 5×10^{-2} mbar within a coating chamber adjacent the preheat chamber;

25 operating an electron beam gun to project an electron beam into the coating chamber and onto a ceramic material, the electron beam melting a coating material within the coating chamber and evaporating molten coating material;

30 moving the article into the coating chamber, the coating chamber containing a condensate hood that at least partially surrounds the article, the condensate hood having a reflective member located within the coating chamber such that the article is between the reflective member and the molten coating material, the reflective member being in a first position relative to

the molten coating material so that the article is subject to reflective heating from the molten coating material;

5 depositing vapors of the coating material on the article; and

10 as the temperature within the coating chamber rises, moving the reflective member to a second position further from the molten coating material so that the article is subject to less reflective heating from the molten coating material.

35. A method according to claim 34, wherein the absolute pressure is established within the coating chamber by first operating a mechanical pump, followed by a cryogenic pump and then a diffusion pump.

15 36. A method according to claim 34, wherein the molten coating material is contained by a fluid-cooled crucible, wherein the electron beam is projected onto the coating material to define an electron beam pattern on the coating material, the apparatus further comprising means for projecting a separate electron beam pattern on the crucible for evaporating droplets of the molten coating material on the crucible, the separate electron beam pattern having a higher pattern intensity than the electron beam pattern on the coating material.

25 37. A method according to claim 36, wherein the separate electron beam pattern is selectively projected while viewing the droplets of the molten coating material through a viewport.

30 38. A method according to claim 34, wherein the coating material is in the form of an ingot supported by a rotatable magazine beneath the coating chamber, the magazine supporting a plurality of ingots of the coating material, the method further comprising the step of the

magazine incrementally aligning each of the ingots with an aperture to the coating chamber for sequentially feeding the ingots into the coating chamber.

5 39. A method according to claim 34, wherein the absolute pressure established within the coating chamber is between about 10^{-2} mbar and 5×10^{-2} mbar.